Computational Design and Analysis of Microwave Tomography in Intracerebral Hemorrhage

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Abstract

Intracerebral hemorrhage is a condition in which a blood vessel in the brain ruptures and causes bleeding preventing the blood flow to particular parts of the brain. This evolves into hemorrhagic stroke leading to degeneration of the brain cells, every minute, resulting in brain damage or death. According to World Stroke Organization 800 in every 100,000 people suffer from stroke each year making it one of the leading causes of mortality worldwide[1-2]. This is diagnosed by a series of Neurological examination with MRI/CT scans and remains as a costly and time consuming process [3]. To overcome this drawback Microwave Tomography (MWT) is proposed to diagnose the occurrence of stroke based on tissue dielectric properties derived from Cole-Cole expression[4].

COMSOL Multiphysics® is used in designing the head phantom with intracerebral hemorrhage from the tissue dielectric values (Figure 1) and the eight dipole antenna array (Figure 2) surrounding the head phantom. The dipole antennas are excited sequentially with 1V port voltage with a characteristic impedance of 50 ohms. The forward solver computes the total electromagnetic field from the head phantom (Figure 3) and the incident electromagnetic field in the absence of the phantom for each of the excited dipole antennas by solving the Maxwell's wave equation in the specified domains [5-7] from the electromagnetic waves physics. Analysis and mapping of the scattered electric field back to the dielectric values was achieved in from the inverse solver such as Contrast Source Inversion (CSI) algorithm[8-9] coded using MATLAB®. An advantage of this method is that no priori data about the phantom dielectric properties except for the dielectric properties of the background medium is required.

The reconstructed relative permittivity value resulting from CSI reconstruction across x=0 axis is shown in Figure 4. The relative permittivity of hemorrhagic domain was computed as 55.64712 as opposed to the designed value of 61 (Figure 4). Upon improving antenna design for improved selectivity and applying regularization for the Inverse problem the accuracy of the MWT system could be improved making it a cost effective, portable means of imaging system.

Keywords: Hemorrhagic stroke, Microwave imaging, Maxwell's wave equation, Contrast Source Inversion (CSI) algorithm.

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Figures used in the abstract

TABLE 1
Dielectical properties of the tissues used in the head model at 1GHz [4]

Tissue	ε_r	σ [S/m]
Skin	41	0.89977
Skull	12	0.15566
CSF	68	2.4552
Grey Matter	52	0.98541
Hemorrhagic	61	1.5829
Dipole antenna (Copper)	1	5.998e7
Free Space (Air)	1	0

Figure 1: Dielectical properties of the tissues used in the head model at 1GHz

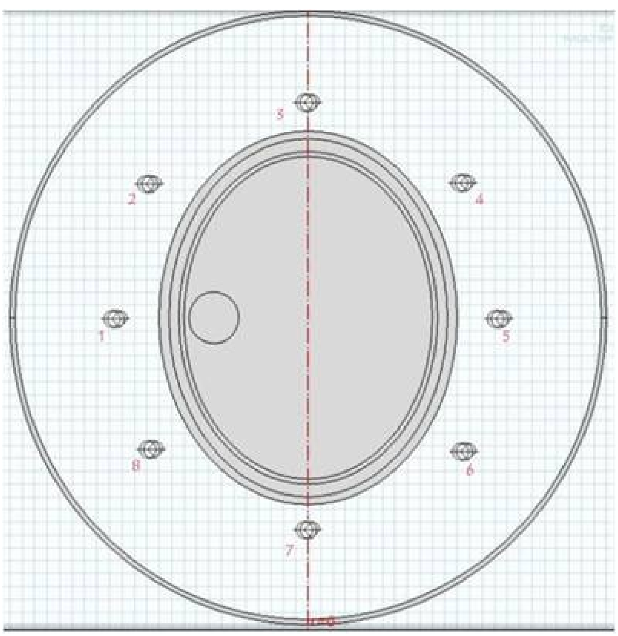

Figure 2: Microwave Tomography Setup with the head phantom consisting domains of hemorrhage, grey matter, cerebrospinal fluid, skull and skin from inside to outside surrounded by an array of eight dipole antennas.

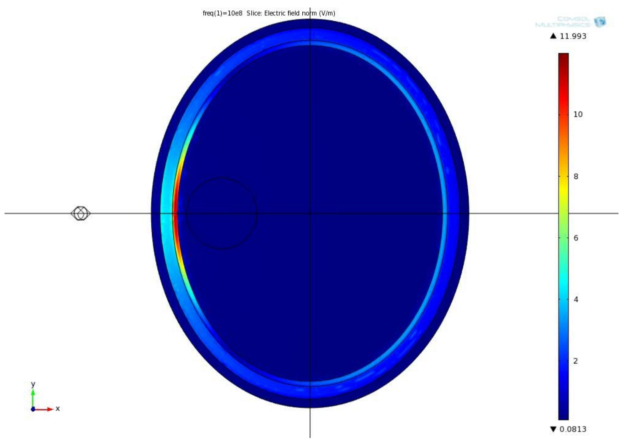

Figure 3: Normalized electric field when the dipole antenna is radiating at 1 GHz at position 1.

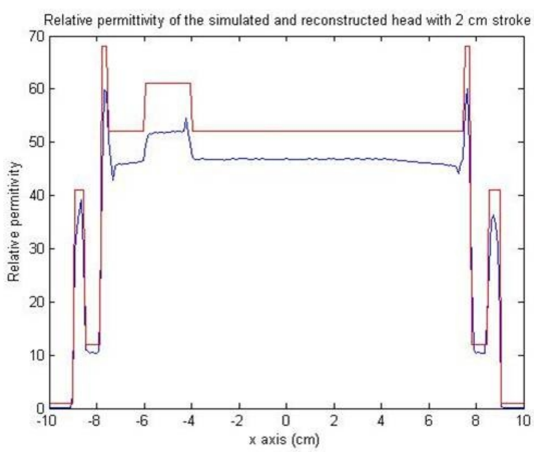

Figure 4: Relative permittivity of the simulated phantom in COMSOL (red) and computed reconstructed value from CSI algorithm in MATLAB (blue) taken across y=0 axis.